We claim:

1. A method for measuring dry density and gravimetric water content of soil, comprising the steps of:

providing a plurality of spikes adapted to be driven into the soil;

driving said plurality of spikes into the soil in spaced relationship;

applying to said plurality of spikes an electrical signal suitable for time domain reflectometry;

analyzing a reflected signal using time domain reflectometry to determine an apparent dielectric constant K_a of the soil and bulk electrical conductivity EC_b of the soil;

calculating dry density ρ_d of the soil using a predetermined relationship between K_a, EC_b and ρ_d ; and

calculating gravimetric water content w of the soil using a predetermined relationship between K_a, EC_b, and w.

2. The method of claim 1, wherein the soil has a surface and the plurality of spikes have a lower end, and the step of analyzing a reflected signal includes measuring the apparent distance between a signal reflected from the surface of the soil and a signal reflected from the lower end of said plurality of spikes to determine an apparent length La.

3. The method of claim 2, wherein said plurality of spikes have a probe length Lp and the apparent dielectric constant $K_a = (La/Lp)^2$.

4. The method of claim 1, wherein the step of analyzing a reflected signal includes measuring a source voltage Vs of the applied signal and a long term voltage Vf of the reflected signal.

5. The method of claim 4, wherein the bulk electrical conductivity $EC_b = (1/C)(Vs/Vf - 1)$ where C is a constant related to probe length Lp.

6. The method of claim 1, wherein the predetermined relationship between K_a, EC_b and ρ_d is $\rho_d = \dfrac{d\sqrt{K_a} - b\sqrt{EC_b}}{ad - cb}$, where *a, b, c* and *d* are soil specific calibration constants.

7. The method of claim 6, wherein calibration constants *a* and *b* are predetermined experimentally for a given soil using the relationship $\sqrt{K_a}\dfrac{\rho_w}{\rho_d} = a + bw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and *w* is the gravimetric water content of the soil.

8. The method of claim 7, wherein EC_b is replaced with an adjusted value $EC_{b,\,adj}$ for which calibration constants c and d are known.

9. The method of claim 1, wherein the predetermined relationship between K_a, EC_b and *w* is $w = \dfrac{c\sqrt{K_a} - a\sqrt{EC_b}}{b\sqrt{EC_b} - d\sqrt{K_a}}$, where *a, b, c* and *d* are soil specific calibration constants.

10. The method of claim 9, wherein calibration constants *c* and *d* are predetermined experimentally for a given soil using the relationship $\sqrt{EC_b}\dfrac{\rho_w}{\rho_d} = c + dw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and *w* is the gravimetric water content of the soil.

11. The method of claim 10, wherein EC_b is replaced with an adjusted value $EC_{b,\,adj}$ for which calibration constants c and d are known.

12. The method of claim 11, wherein the calculated value of K_a at a given temperature is adjusted to a value $K_{a,\,20°C}$ at a standard temperature of 20°C, where

$$K_{a,20^\circ C} = K_{a,T} \times TCF$$

and where TCF = Temperature Compensation Function

$= 0.97 + 0.0015\ T_{test,°C}$ for cohesionless soils, $4°C \leq T_{test,\,°C} \leq 40°C$

$= 1.10 - 0.005\ T_{test,°C}$ for cohesive soils, $4°C \leq T_{test,\,°C} \leq 40°C$.

13. A method for measuring dry density of soil, comprising the steps of:

providing a plurality of spikes adapted to be driven into the soil;

driving said plurality of spikes into the soil in spaced relationship;

applying to said plurality of spikes an electrical signal suitable for time domain reflectometry;

analyzing a reflected signal using time domain reflectometry to determine an apparent dielectric constant K_a of the soil and bulk electrical conductivity EC_b of the soil; and

calculating dry density ρ_d of the soil using a predetermined relationship between K_a, EC_b and ρ_d.

14. The method of claim 13, wherein the predetermined relationship between K_a, EC_b and ρ_d is $\rho_d = \dfrac{d\sqrt{K_a} - b\sqrt{EC_b}}{ad - cb}$, where a, b, c and d are soil specific calibration constants.

15. The method of claim 14, wherein calibration constants a and b are predetermined experimentally for a given soil using the relationship $\sqrt{K_a}\dfrac{\rho_w}{\rho_d} = a + bw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and w is the gravimetric water content of the soil.

16. The method of claim 14, wherein calibration constants c and d are predetermined experimentally for a given soil using the relationship $\sqrt{EC_b}\,\frac{\rho_w}{\rho_d} = c + dw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and w is the gravimetric water content of the soil.

17. The method of claim 14, wherein EC_b is replaced with an adjusted value $EC_{b,\,adj}$ for which calibration constants c and d are known.

18. The method of claim 17, wherein the calculated value of K_a at a given temperature is adjusted to a value $K_{a,\,20°C}$ at a standard temperature of 20°C, where

$$K_{a,20^{\circ}C} = K_{a,T} \times TCF$$

and where TCF = Temperature Compensation Function

$= 0.97 + 0.0015\ T_{test,°C}$ for cohesionless soils, $4°C \leq T_{test,\,°C} \leq 40°C$

$= 1.10 - 0.005\ T_{test,°C}$ for cohesive soils, $4°C \leq T_{test,\,°C} \leq 40°C$.

19. A method for measuring gravimetric water content of soil, comprising the steps of:

providing a plurality of spikes adapted to be driven into the soil;

driving said plurality of spikes into the soil in spaced relationship;

applying to said plurality of spikes an electrical signal suitable for time domain reflectometry;

analyzing a reflected signal using time domain reflectometry to determine an apparent dielectric constant K_a of the soil and bulk electrical conductivity EC_b of the soil; and

calculating gravimetric water content w of the soil using a predetermined relationship between K_a, EC_b, and w.

20. The method of claim 19, wherein the predetermined relationship between K_a, EC_b and w is $w = \frac{c\sqrt{K_a} - a\sqrt{EC_b}}{b\sqrt{EC_b} - d\sqrt{K_a}}$, where a, b, c and d are soil specific calibration constants.

21. The method of claim 20, wherein calibration constants a and b are predetermined experimentally for a given soil using the relationship $\sqrt{K_a}\frac{\rho_w}{\rho_d} = a + bw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and w is the gravimetric water content of the soil.

22. The method of claim 20, wherein calibration constants c and d are predetermined experimentally for a given soil using the relationship $\sqrt{EC_b}\frac{\rho_w}{\rho_d} = c + dw$, where ρ_w is the density of water, ρ_d is the dry density of the soil, and w is the gravimetric water content of the soil.

23. The method of claim 22, wherein EC_b is replaced with an adjusted value $EC_{b,\ adj}$ for which calibration constants c and d are known.

24. The method of claim 23, wherein the calculated value of K_a at a given temperature is adjusted to a value $K_{a,\ 20°C}$ at a standard temperature of 20°C, where

$$K_{a,20^\circ C} = K_{a,T} \times TCF$$

and where TCF = Temperature Compensation Function

$= 0.97 + 0.0015\ T_{test,°C}$ for cohesionless soils, $4°C \leq T_{test,\ °C} \leq 40°C$

$= 1.10 - 0.005\ T_{test,°C}$ for cohesive soils, $4°C \leq T_{test,\ °C} \leq 40°C$.

25. An apparatus for measuring dry density of soil, comprising:

a plurality of spikes adapted to be driven into the soil in spaced relationship;

means for applying to said plurality of spikes an electrical signal suitable for time domain reflectometry;

means for analyzing a reflected signal using time domain reflectometry to determine an apparent dielectric constant K_a of the soil and bulk electrical conductivity EC_b of the soil; and

means for calculating dry density ρ_d of the soil using a predetermined relationship between K_a, EC_b and ρ_d.

26. The apparatus of claim 25, wherein the predetermined relationship between K_a, EC_b and ρ_d is $\rho_d = \frac{d\sqrt{K_a} - b\sqrt{EC_b}}{ad - cb}$, where a, b, c and d are soil specific calibration constants.

27. The apparatus of claim 26, further comprising means for calculating gravimetric water content w of the soil using a predetermined relationship between K_a, EC_b, and w.

28. The apparatus of claim 25, further comprising means for compensating for soil temperature.

29. An apparatus for measuring gravimetric water content of soil, comprising:

a plurality of spikes adapted to be driven into the soil in spaced relationship;

means for applying to said plurality of spikes an electrical signal suitable for time domain reflectometry;

means for analyzing a reflected signal using time domain reflectometry to determine an apparent dielectric constant K_a of the soil and bulk electrical conductivity EC_b of the soil; and

means for calculating gravimetric water content w of the soil using a predetermined relationship between K_a, EC_b, and w.

30. The apparatus of claim 29, wherein the predetermined relationship between K_a, EC_b and w is $w = \frac{c\sqrt{K_a} - a\sqrt{EC_b}}{b\sqrt{EC_b} - d\sqrt{K_a}}$, where a, b, c and d are soil specific calibration constants.

31. The apparatus of claim 29, further comprising means for compensating for soil temperature.